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IDENTIFYING ECONOMICAL READINESS OPTIONS: A COST RATIO TEST

By

Dr. P.F. O'Neill
Joint Staff Operational Research Team

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OTTAWA, CANADA

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ABSTRACT

This report describes a cost estimation relationship for readiness options. It is the result of work carried out in conjunction with the NATO Specialist Team on the Evaluation of Readiness and Sustainment Policy. After providing background information on cost estimation, a ratio test is derived for identifying economical options for maintaining and generating operationally ready forces. Formulae are given for estimating cost savings over a planning horizon.

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IDENTIFYING ECONOMICAL READINESS OPTIONS: A COST RATIO TEST

BACKGROUND

1. The current decade has seen significant changes in world order. As a consequence of these changes, planners must assess a broad spectrum of options for rationalising and re-designing armed forces. In many cases, armed forces must be prepared to respond to a greater diversity of potential conflict. More specifically, the broad spectrum of options can include greater latitude for varying the response time of force generation.

2. Inherent in the assessment of military capability requirements, is the need to evaluate the time and resource requirements for force generation. Methodology is needed to analyse force surge processes against the resources and infrastructure assigned to accomplish stated objectives. In particular, methodology is needed to assist planners with identifying and evaluating trade-offs between time, resources, processes and budgetary costs.

3. The author served as chairman of the NATO Panel 7 Specialist Team on the Evaluation of Readiness and Sustainment Policy. This team was formed in 1994 to examine methodologies for evaluating readiness. The Team was tasked with:

a. surveying existing methods for readiness evaluation;

b. devising methodologies for evaluating joint readiness;

c. devising methodologies for evaluating flexible readiness; and,

d. deriving cost estimation relationships to assess the potential monetary impact of readiness options.

4. Results of the work of the Specialist Teams are reported in Reference 1. In particular, a comprehensive methodology that addresses tasks (ii) and (iii) is described. Cost estimation is also dealt with at some length.

5. Managers of defence departments and armed forces are motivated to reduce budgets and to glean greater efficiency from spending on military capability. Thus, the art and science of cost estimation is of importance because it provides the basis for investigating ways of becoming more efficient. By exploring cause and effect relationships in spending patterns, managers can improve the return on money invested in military capability.

6. More specifically, cost estimation of readiness options is of interest because cost estimation can provide a means for identifying areas of potential cost reductions. For example, reduction in the cost of operations and maintenance, training, logistic support and infrastructure might be derived from judicious cost analysis of readiness options.

7. This note presents an additional result from subsequent work related to task (iv). A ratio test that can be used to identify economical readiness options will be described. Prior to the ratio test, however, some background information on activity-based costing and cost estimation (from References 1 and 2) is given for the sake of completeness.

ACTIVITY-BASED COSTING

8. Intuitively, an "activity" is something that must be done in order to accomplish an objective. In corporate circles, an "activity" describes the way an enterprise employs its time and resources in order to achieve corporate objectives. In technologically advanced organisations, it is economically valuable to model cost effectiveness in terms of activities because traditional accounting methods fail to correctly attribute the relative value of human resources to specific "outputs" in organisations where technology contributes significantly and in varying degrees to the outputs. A greater proportion of indirect costs (overhead) including technology costs and information processing costs now contributes to the total cost of maintaining and deploying armed forces than it ever did before. For this reason, many defence departments, including DND, are moving toward Activity-Based Costing, (ABC).

9. Beyond the issue of attributing overhead costs to outputs, ABC provides a means to relate performance measures for activities at each stage of a process to the ultimate outputs and thereby to enable cost-effective programs for continuous improvement of processes. A resource and activity-based model of an organisation's inputs, processes and outputs provides a means of predicting consequences of decisions. In this context, if the "output" is taken as capability within a given response time, then ABC is a useful tool for analysing the cost effectiveness of readiness-related processes and decision-making in defence organisations

10. Activities currently form the foundation of many cost management systems, as businesses and government organisations move toward activity-based costing. Successful implementation of activity-based costing has helped various organisations to improve their work processes, to identify cost drivers and to control costs. Moreover, implementation of activity-based costing has given managers the information they need to improve their operational and strategic decision-making.

11. In the public sector, it is useful to define an activity as "an element of work which turns resources into outputs". In the context of readiness evaluation, it is natural to describe both steady-state capability maintenance processes and capability surge processes in terms of "activities" where "outputs" are defined military capabilities that satisfy prescribed task standards.

12. Activity-based cost analysis can be used to identify any parts of operational or support processes that do not add value to a final product. For costing readiness options, ABC can be used to analyse the cost of maintaining and surging capabilities and consequently to provide knowledge of where and how resources are being consumed. Current or proposed consumption of resources can then be rated against planning priorities and adjustments can be made to improve the effectiveness of budgetary allocations.

13. ABC costing involves detailed breakdown of the final outputs into the various activities that contribute to them. For readiness costing, this breakdown can use capability-based plans as a starting point. ABC analysis then determines why resources are consumed to complete individual activities. The "whys" of ABC are known as cost drivers. The role of the cost analyst is to collect and allocate direct and indirect costs to individual activities, using these cost drivers.

Methods for Estimating Costs

14. Cost estimation is as much an art as a science, especially when compared to financial accounting. There is no absolute method for determining costs. However, any sound costing approach must be logical and the constituent cost data that it uses must be valid and verifiable.

15. There are four main cost estimating methods in general use: the engineering method, the parametric method, the analogy method and the expert opinion method. The use of a specific method varies with the amount and reliability of available data. Furthermore, more than one cost estimating method may be used in the preparation of estimates for decision-making purposes. A brief description of each of the methods follows:

a. **Engineering Method:** (bottom-up method) requires that the system be divided into segments and that the cost of each segment be estimated. The segment costs are then combined together with any integration costs to arrive at the total cost. A major limitation of the integration method is that it requires extensive knowledge of the system. Also, it requires knowledge of the development and production processes. For new technologies, detailed knowledge required for the complete engineering method is not always available.

b. **Parametric Method:** makes use of formulae that express general relationships. These are derived from statistical analysis of past projects and relate costs to one or more technical or physical characteristics. This method depends intimately on the establishment of valid relationships between costs and characteristics. Lack of data may limit the use of this technique.

c. **Analogy Method:** assesses the cost of a project as a whole, or its constituent parts, by comparison with previous projects, allowing for differences in type, complexity, technological change or scale. This method is in essence an extrapolation from the past rather than a statistical or engineering attempt to establish a formula. This method requires considerable expertise and judgement skill and assumes that similar systems are known in some detail.

d. **Expert Opinion Method:** draws upon the subjective judgement of an experienced individual or group. Estimates based on this Method usually lack detailed rationale and analysis and subsequently lack a good level of confidence. This method should not be used if scientific methods are possible.

16. An activity-oriented approach to readiness evaluation lends itself readily to the engineering method and the parametric method, although the other two methods might be useful in some cases. For example, in cases where only direct operating costs or incremental costs need to be considered, the engineering method and the parametric method are sufficient for many cost analyses. However, if previously untried training options or equipment maintenance options are being costed, either of both of the analogy method and the expert opinion method might be needed in order to assemble enough information to make a reliable cost estimate.

Cost Estimation Considerations

17. Cost estimation is a time-consuming and complex process requiring access to a wide range of information and techniques. Cost estimates, like all types of estimates, are approximations and therefore carry an inherent uncertainty in their accuracy. Approximations are often based on statistical analysis of data or a mathematical model. Consequently, approximations can be refined by some combination of enlarging the sample size of the data and increasing the sophistication of the statistical analysis or models used to make the estimate.

18. Both enlarging the sample size and increasing the sophistication of the analysis require additional effort and might result in an insignificant improvement of the approximation. The required degree of costing precision depends upon the purpose of the estimate and the ease of identifying the costs involved. To determine the level of detail and accuracy required, a cost-benefit analysis can indicate the relative worth of refining the estimate compared to the cost of making the refinement.

19. When developing the full costs of options, the complex issue of **cost allocation** has to be addressed. This is the process that is required to attribute overhead and indirect costs to appropriate activities in a way that quantitatively and meaningfully links such costs to resource consumption and outputs.

20. The allocation of common costs is usually required for managerial purposes such as recovery and planning decisions. The allocation process involves three principal steps:

a. accumulating the costs related to the system, activity or operations;

b. identifying the recipients/consumers of the allocated costs; and

c. selecting a basis to relate the costs to the recipients/consumers.

The last step is the most difficult. Typically, the allocation basis is selected on empirical grounds that serve the main intention of performing the cost estimate.

22. Cost estimation is often based on statistical analysis of cost-related data. The uncertainty inherent in statistical analysis gives rise to a number of typical errors:

a. double counting - including the same cost element in more than one portion of the estimate;

b. omissions - overlooking costs that apply to the estimate;

c. hidden costs - costs that result from ill-defined categories, nondisclosure of certain costs or improper allocation of overhead;

d. spill over costs - costs that result from secondary effects not considered.

Costing Concepts

23. There are two useful concepts to guide cost estimation processes:

a. **Relevant Costs** - include only those costs that are relevant and consequential. For example, when analysing a number of readiness options, there may be resources with the same usage whatever the option. Such resources can be considered irrelevant in the costing context unless it is required to determine the total cost for an activity.

b. **Control Over Costs** - resource managers seldom have complete control over all the costs of all the resources at their disposal. The analysis must distinguish between costs that are controlled by managers and those costs that are attributable but over which there is no control.

Types of Costs

24. Any costs not changed by changes in an activity are known as **fixed** costs. If a change in an activity requires use of additional resources, the costs related to these resources are known as **incremental** costs. Incremental costs can be **fixed** or **variable** in nature. When comparing alternatives, incremental costs are of prime importance.

25. Costs will either have a **direct** or **indirect** relationship to particular goods and services. Direct costs can be directly attributed to producing or providing a good or service, and will increase or decrease in direct proportion to a change in level or activity (e.g. basic pay). Indirect costs on the other hand are those costs that cannot be precisely attributed to producing or providing specific goods and services. Indirect costs are those that cannot be effectively linked to an individual's rank, but can be incurred for each regular force person (e.g. state-funded health care costs).

Costing Approaches

26. The costing approach that is used should be considered carefully so that any options analysis conducted later can conform to the selected approach in the interests of consistency and fairness. The major approaches are the following:

a. **Incremental Cost Approach**: the incremental cost approach seeks to identify costs that are directly and precisely attributable to the activity or process being costed out; this approach is most commonly used in situations where the activities have clear organisational boundaries and all of the resources can be controlled. The incremental cost approach can be used to support efforts to reduce resource inputs to achieve the same level of outputs. Overhead costs such as base support costs are not considered relevant, unless they can be specifically identified with the area being examined and are known to vary with changes in the activities.

b. **Operating Cost Approach**: the operating cost approach takes a wider view of the options at hand seeking to cost them in greater detail. This approach will identify all costs that impact on the organisation at large regardless of whom may exercise control over those costs. It is more suitable to larger and wider reaching cases and includes an examination and exploration of fixed and overhead costs to determine their relationships with the organisation to see if anything can be done about them when finalising options. However, the distinction between costs that

are rolled up for analysis and consequential or avoidable costs must be maintained; i.e. costs used for decision-making purposes must be relevant and controllable. For this reason capital costs, such as depreciation and attrition are not considered in this type of analysis. The operating cost approach is suitable in situations where a complete function or activity is being considered for privatisation.

c. **Full Cost Approach**: the full cost approach identifies all costs associated with the organisation, including allocated overheads and capital related costs. This approach is useful in large-scale case analysis where it is important to understand the relative value of competing options and life cycle cost issues.

Cost Categories

27. Cost categories represent the resources that are used. These categories are further sub-divided into direct and indirect costs. For purposes of readiness cost estimation, many of the driving costs can be extracted from the cost factors manual.

a. **Personnel Costs:** These are the costs of all the relevant military and civilian personnel resources further subdivided based on who controls the cost. A number of managers might be impacted by changes to personnel resources.

b. **Equipment Costs:** These include direct and indirect costs of operating equipment used within the activity or business boundaries, further subdivided based on who controls the costs. For example, a particular manager may be able to control the direct operating costs and local maintenance costs for a major piece of equipment but the major repair costs might be controlled by someone else. In such cases, the fact that different budget managers pay for different aspects of maintenance does not change the fact that savings would be achieved if the equipment were eliminated – the issue is how the savings will be captured and recorded.

c. **Facilities Costs:** Facilities costs are sub-divided based on control over the costs. Particular attention should be exercised in identifying if there are any real savings or costs associated with the use or change in use of facilities. Facilities costs are often sunk costs that will not result in any true savings, except in cases where the options deal expressly with

facilities issues.

d. **Other Costs and Offsetting Revenue:** It is necessary to include costs that do not fall into one of the other resource categories and to capture any direct and indirect revenues that may be associated with options.

Time

28. The time over which costs are incurred can have a significant bearing on the decision at hand. The following issues should be considered when dealing with the time dimension:

a. **Selection of the time line**: the cost analysis can be concerned with identifying a one-time saving in a single year, recurring savings from year to year, life cycle cost savings over the entire life of an equipment, or identifying the number of years for an initiative to be effective in saving money. The baseline cost should be structured in the same way as the options will be costed and must cover the same time period. The timeline for business case analysis should be carefully chosen to best suit the aim.

b. **Inflation**: whenever time is introduced, the effects of inflation will have to be considered; in some cases it may not be necessary to calculate inflated costs.

c. **Time Value of Money**: In some situations this should be considered.

29. The four major ways that the results of the quantitative assessment can be reported are as follows:

Constant Year Dollars - both time value of money and inflation are not considered;

Budget Year Dollars - inflation considered but not the time value of money;

Net Present Value - time value of money considered - NVP is particularly useful with capital projects and life cycle costing; and

Payback Interval - a determination of how long it will take the saving of a proposal to re-pay the initial expenditure.

READINESS RATIO TEST

30. Suppose that over a planning period of m years, it is estimated that a certain capability will be generated n times per year on average. Let C denote the expected annual steady state cost of the capability and let S denote the expected cost that will be incurred if the capability has to be generated to task standards. Then, the required annual budget, B, of the capability is estimated by:

$$B = C + nS$$

31. Suppose further that there are alternatives for generating this capability. If the alternatives are distinguished by subscripts 1 and 2, and we adopt the convention that the second alternative has a lower expected annual cost, then the annual expected budgets for the alternatives are estimated by:

$$B_1 = C_1 + nS_1,$$
$$B_2 = C_2 + nS_2,$$

with $B_2 < B_1$.

32. Because the value of n may be difficult to estimate with much confidence, it is instructive to consider under what conditions the second alternative will be more economical than the first. Consider 2 straightforward cases:

a. clearly, if $C_2 < C_1$ and $S_2 \leq S_1$ then the second alternative is always the more economical.

b. if $C_2 = C_1$ and $S_2 < S_1$ then provided that the non-recurring set-up costs to implement option 2 are sufficiently low, option 2 is more desirable. This corresponds to a situation in which a lower cost alternative for the capability surge process is being considered, while leaving the steady state cost unaltered.

33. Lowering steady-state O&M costs is a high priority goal of the planning process and consequently alternatives that satisfy $C_2 < C_1$ are of special interest to decision makers. It is often the case, however, that by lowering the steady state cost of maintaining a capability, a higher surge cost will result especially if the same operational capability standards are invoked under the new plan.

34. A higher surge cost results because steady state savings are realised by lowering training, equipment and stockpile benchmarks which will subsequently have to be redressed during the surge process in order to achieve the same operational standards. Such a situation is characterised by the conditions $C_2 < C_1$ and $S_2 > S_1$. Under this contingency,

$$
\begin{aligned}
& B_2 < B_1 \\
& \Rightarrow C_2 + nS_2 < C_1 + nS_1 \\
& \Rightarrow n \times (S_2 - S_1) < (C_1 - C_2) \\
& \Rightarrow n < \left(\frac{C_1 - C_2}{S_2 - S_1} \right)
\end{aligned}
$$

35. Planners might choose to include an estimate for potential unnecessary spending on training, maintenance, re-fit or transportation for options with a longer surge time. For long surge options there may be a significant probability that the surge process might be cancelled prior to the actual employment of the capability.

36. Let the ratio $\alpha = \left(\frac{C_1 - C_2}{S_2 - S_1} \right)$ be referred to as the Cost Difference Ratio (CDR) and let the condition $n < \alpha$ be referred to as the Ratio Test. Note that because it is a ratio, the value of α is independent of inflation, if the costs of options 1 and 2 are expressed in the same terms.

37. The Ratio Test can be used to identify options that will likely result in lower spending. Consider three cases:

a. Suppose that the surge cost difference between the options is *small* relative to the steady state cost difference. That is to say, suppose $\alpha >> 1$. Here, the Ratio Test implies that for a wide range of values of n, the

second alternative is more economical than the first. Thus, if the predicted value of n satisfies the condition $n < \alpha$ with good assurance, then there is good assurance that implementing option 2 will result in lower spending.

b. Suppose that the surge cost difference is approximately the same as the steady state cost difference; or stated equivalently on terms of the cost difference ratio, suppose $\alpha \approx 1$. Depending upon the actual size of α, if it is known with good assurance that generating the capability will be a low frequency event, then option 2 will likely result in lower cost.

c. Suppose that the surge cost difference is large relative to the steady state cost difference. In this case $\alpha << 1$ and hence, satisfying the Ratio Test will require $n \approx 0$. This implies that if the capability is unlikely ever to be generated, then option 2 will likely to result in lower spending. In such a situation, because the probability of ever surging the capability to operational standards is very low, surge costs are unlikely ever to be incurred. Here, the cost driver is the steady state cost, which is lower for option 2.

Economy of High Readiness

38. According to the Ratio Test, the condition $n > \alpha$ indicates that option 1 is probably more economical than option 2. By following the inverse logic of case (i) above, capabilities that are frequently surged should be maintained with relatively lower "surge" costs and relatively higher "steady state" costs. In fact, it is apparent from the Ratio Test, that for such capabilities, the "steady state" should actually constitute a continuing short period cycle of "surges" with no distinctive surge process apart from what is accomplished cyclically in the "steady state".

39. By adopting such a policy, recurring set-up costs for the "surge" process can be minimised (or even eliminated) by keeping surge mechanisms functioning on a continuing basis and thereby subsuming their costs into the overall "steady state" cost. Capabilities that are characterised by high surge frequency constitute capabilities that warrant so-called "high readiness". Thus, the ratio Test indicates that economy might be had for such capabilities by eliminating or at least minimising any part of the process that can be characterised as a "surge" phase and subsuming capability generation activities into the "steady state".

Estimating Cost Savings

40. The expected annual budgetary savings, Δ, from invoking option 2 instead of option 1 is estimated by:

$$\begin{aligned}\Delta &= B_1 - B_2 \\ &= (C_1 + nS_1) - (C_2 + nS_2) \\ &= (C_1 - C_2) + n(S_1 - S_2) \\ &= \alpha(S_2 - S_1) + n(S_1 - S_2) \\ &= (\alpha - n)(S_2 - S_1)\end{aligned}$$

41. This formula expresses the expected annual savings in terms of cost ratio, expected frequency of surge and surge cost difference. An inflation factor of $(1+r)^i$ can be used to adjust the value of Δ for inflation in year i if the expected annual inflation rate is r.

42. If a one-time initial set-up cost of A is invested to invoke option 2, then the break-even point will occur in Y years where:

$$Y = \frac{\log\left(\frac{rA}{\Delta} + 1\right)}{\log(r+1)}$$

43. If the inflation rate is low (< 5%) and the planning horizon is approximately 10 years or less then (by L'Hospital's Rule):

$$Y \approx \frac{(r+1)}{\left(r + \Delta/A\right)}$$

Thus, as $r \to 0$, $Y \to \frac{A}{\Delta}$. (Note that the approximation yields the obvious result when $r = 0$.)

44. The estimated total savings over the planning horizon is given by:

$$\Sigma = \Delta\left(\frac{(1+r)^m - 1}{r}\right) > \frac{mA}{Y}$$

45. Using the binomial theorem:

$$(1+r)^m = 1+mr+\frac{m\times(m+1)}{2}r^2+\frac{m\times(m+1)\times(m+2)}{6}r^3+\ldots$$

an approximation for the total savings is given by:

$$\Sigma \approx m\left(1+\frac{m}{2}r\right)\Delta$$

Examples

Case (1)

46. Consider a capability with an annual Operation and Maintenance (O&M) cost of $10 million and a surge cost of $1 million for each operational employment. Suppose that an alternative equipment O&M policy is proposed that would bring the capability cost to $9.3 million annually with a surge cost of $1.25 million per employment. Suppose that $1 million (in terms of current year dollars) would have to be spent to implement the new policy. Should the proposed policy be adopted?

47. The cost difference ratio is given by $\alpha = \frac{(10-9.3)}{(1.25-1.)} = 2.8$. Therefore, if the capability is expected to be employed operationally less than 3 times per year, it is cost effective to adopt the proposed policy.

48. Suppose that within the last 6 years the capability has been employed 3 times in total. Then, the expected annual employment rate for the capability is 0.5 and the expected annual saving is given by :

$$(10-9.3)+0.5\times(1.25-1.)=0.825$$

This represents $825,000 per year in expected savings.

49. If the predicted annual inflation rate is 1.9% then the break even point is given by:

$$Y=\frac{\log\left(\frac{rA}{\Delta}+1\right)}{\log(r+1)}=\frac{\log\left(\frac{.019\times 1}{.825}+1\right)}{\log(.019+1)}=1.21$$

50. So, the investment of CY$1 million is expected to payoff in roughly 5 quarters. Therefore, the proposed new policy is economical.

Case (2)

51. Consider a capability which has an annual O&M cost of $10 million and a surge cost of $5 million per employment. Suppose that by closing a training facility and contracting its activities, the O&M cost can be brought to $9.3 million per year with a surge cost of $5.1 million per employment. However, suppose it is known that if the training functions are turned over to the private sector then, because of course loading constraints, the capability can be generated no more than 5 times per year and that this limitation is acceptable from an operational standpoint. Suppose further that the facility closure will require a layout of $7 million. Should the training facility be closed and its functions be purchased externally?

52. In this case, $\alpha = \frac{(10-9.3)}{(5.1-5)} = 7$. The fact that the capability will be limited to at most 5 activations per year implies that it is economical to contract the training functions. The expected annual savings will depend upon the utilisation rate of the capability and can vary between $0.7 million (if the capability is generated 0 times) and $1.2 million per year (if the capability is generated 5 times). The break-even point lies between 8.56 (based on 0 occurrences) and 5.35 years (based on 5 occurrences), using an annual inflation rate of 1.9%.

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This report describes a cost estimation relationship for readiness options. It is the result of work carried out in conjunction with the NATO Specialist Team on the Evaluation of Readiness and Sustainment Policy. After providing background information on cost estimation, a ratio test is derived for identifying economical options for maintaining and generating operationally ready forces. Formulae are given for estimating cost savings over a planning horizon.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus-identified . If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

Readiness Evaluation
Cost Estimation Relationships
Business Planning
Activity Based Costing
Risk Management
Risk Analysis